## *ON SOME POINTS IN THE EARLY HISTORY OF ASTRONOMY.*[1]

### III.

WE now come to the important point for our present inquiry—the direction in which the temple is built, or, technically, its orientation. Confining ourselves for the moment to Karnak, is there any meaning in the direction of that line, some 500 yards long, which is obviously the main feature of the building, and to which all parts are accessories?

How can we instrumentally determine this? I have the necessary apparatus here, and the question may be answered in a few minutes; we have simply to determine either the azimuth or the amplitude (and as we have seen one of these gives the other) of the point of the horizon towards which this long line is directed.

The azimuth compass is an instrument familiar to most of you. It consists of a magnetic needle fastened to a card carrying a circle divided into 360°, which can be conveniently read by a prism when the instrument is turned toward any definite direction marked by a vertical wire.

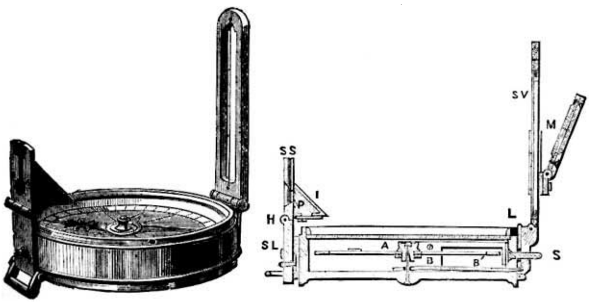

FIG. 11.—Azimuth compass. SV, direction pointer; M, sun shade (for observations of sun); I, reading prism; A B, graduated card with attached compass-needle.

A theodolite armed with a delicately hung magnetic needle which can be rotated on a vertical axis will do equally well; it has first of all to be levelled; there is a little telescope with which we can see along the line.

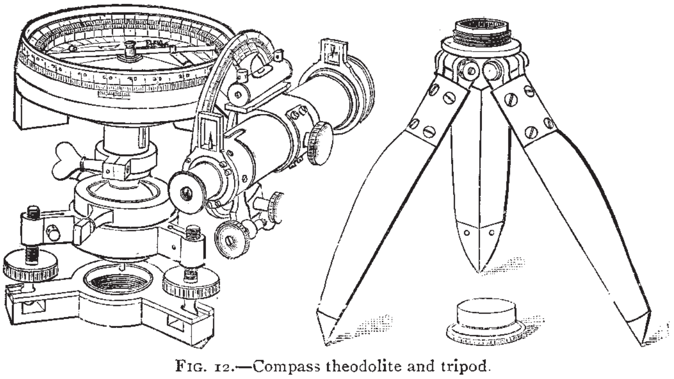

FIG. 12.—Compass theodolite and tripod.

When we wish, for instance, to observe the amplitude of a temple, the theodolite is set up on its tripod in such a position that we can look along the temple wall or line of columns, &c., by means of the telescope. We then get a magnetic reading of the direction, after having unclamped the compass; the compass showing the angle made between the line and the magnetic north (or south), as in the azimuth compass.

Having made such an observation as that I have described, the next thing we have to do is to determine astronomically the real north, which is the only thing of value. There are two ways of getting this *astronomical* bearing or azimuth.

It is sad to think how much time has been lost in the investigation of a great many of these questions, for the reason that the observations were made only with reference to the magnetic north, which is vastly different at different places, and is always varying; few indeed have tried to get at the astronomical conditions of the problem. Had this been done either by the French or Prussian Commissions to which I have referred, it is perfectly certain that years ago the solstitial orientation of Karnak and other temples which I shall have to demonstrate to you would have been long known to all scholars.

If the magnetic variation has been determined for the region we may use a map. Such a map as that shown in Fig. 13 gives us the lines along which in the British Isles the compass variation west of north reaches certain values. From such a map for Egypt we learn that in 1798 a magnet swung along a line extending from a little to the west of Cairo to the second cataract would have had a variation of 12° to the west; in 1844 of 8° to the west; and at the present time the variation is such that observations made along the same part of the Nile valley will have a variation closely approximating 5° to the west. By means of such a map it is quite possible to get approximately the astronomical bearings of all temples which were observed by the French in 1798 or by the Germans in 1844, or which can be observed in the present day.

If we are not fortunate enough to possess such a map, the theodolite will enable us to observe the direction in which the sun culminates at noon. This gives us the south point astronomically. From observations of the pole star at night, the astronomical north can be determined. From either of these observations the magnetic variation is obtained without any difficulty.

This being premised about the method, we next come to the results. The amplitude of the point to which the axis of the great temple at Karnak points is 26° N. of W., which we learn from the table already given is precisely the amplitude of the place of sunset at the summer solstice. The amplitude of the point to which the axis of the small temple points is 26° S. of E., exactly the position of sunrise at the winter solstice.

There is more evidence of this kind. Abydos, one of the oldest temples in Egypt, built, according to tradition, by the servants of Hor, is now, it is true, a heap of ruins, the brick walls best showing its direction; but it is possible to gather the orientation of it by these guiding lines. It is 27° N. of W.—as it should be, being in a higher latitude than Karnak—and evidently was oriented to the solstice.

At Abydos, then, as at Karnak, we get exactly, within a degree, the amplitude shown in the tables for the sun in the Nile valley at sunset at the summer solstice. So that the Egyptians who were employed in building those temples must have known exactly what they were going to do, and what they did was to build a temple such that the sun at setting should, at the summer solstice, pour its light along the axis of the temple. If Maspéro and the great authorities in Egyptian archæology are right—namely, that the Abydos temple was founded before 4000 B.C.—and if we can depend upon the French figures, we are driven to the conclusion that we have in this temple a building which was orientated to the solstitial sunset place in the valley of the Nile. The Nile valley holds other solar temples besides those we have named, but it is best to fully study Karnak; instead of being a mere heap, the orientation of which is obtainable only by the general lie of the remains, this temple is still in such preservation that the Germans, in the year 1844, could give us an infinite number of details about it, and locate the position of the innumerable courts. Its orientation to the solstice we can claim as an early astronomical observation. So it is quite fair to say that, many thousand years ago at all events, the Egyptians were perfectly familiar with the solstices, and therefore more or less fully with the yearly path of the sun.

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[1] Continued from p. 11.

But so far we have only dealt with solstices. Did the Egyptians know anything about the equinoxes? Certainly. Nothing is more remarkable than to go from the description and the plans of such temples as we have seen at Abydos and Karnak to regions where, apparently, the thought is totally and completely different, such as we find on the Pyramid Plains at Ghizeh; the orientation lines of the German surveyors show, beyond all question, that these structures are just as true to the sun-rising at the equinoxes as the temples at Abydos and Karnak were to the sun-rising and setting at the solstices, and the Sphinx was merely a mysterious nondescript sort of thing which was there watching for the rising of the sun at an equinox, as the Colossi of the plain at Thebes were watching for the rising of the sun at the winter solstice.

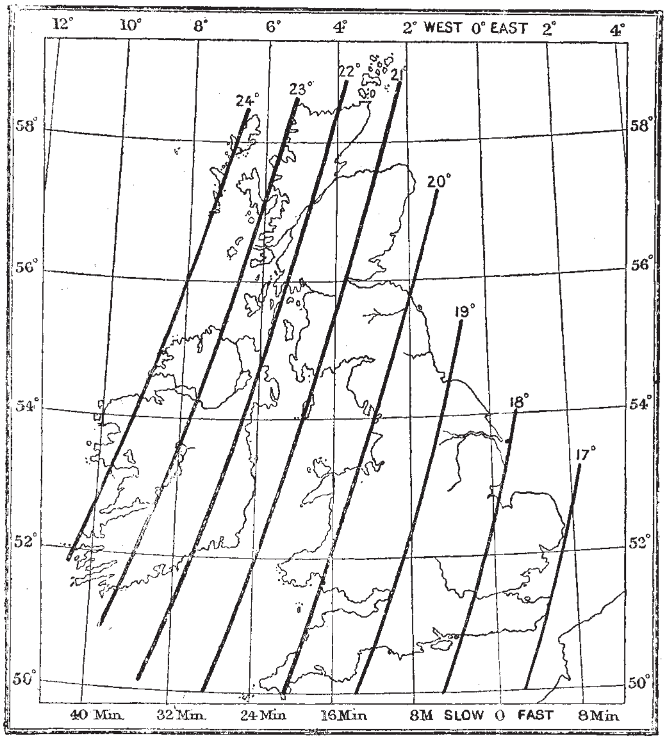

FIG. 13.—Map of British Isles showing the magnetic variation.[1]

The observations which have been made in Babylonia are very discordant among themselves, and at present it is impossible to say, from the monuments in any of this region along the Euphrates valley, whether the temples indicate that the solstices were familiar to the Babylonians; but no doubt some of the temples were as perfectly squared to the equinox as some walls at Memphis or the Pyramids at Ghizeh; and certainly there is no doubt that as early as Solomon's time the temple at Jerusalem was orientated to the east with care. We find there that the direction of the axis of the temple shows the existence of a cult connected with the possibility of seeing the rising of the sun on the day of an equinox, possibly at the time which we now call Easter.

All the doors being opened, the sunlight would penetrate over the high altar, where the sacrifices were offered, into the very Holy of Holies, which we may remember was only entered by the High Priest once a year.

Have we any other evidence except the evidence afforded by temples? Yes. It has been stated that we have no temple evidence from China, but there is a good deal of written evidence, and there is no doubt that in China the solstices and the equinoxes were perfectly well known 1100 years B.C. Was it difficult to obtain this knowledge? Did it indicate that the people were great astronomers? Nothing of the kind; nothing is so easy as to determine a solstice or an equinox.

We know from the Egyptian tombs that their stock-in-trade, so far as building went, was very considerable; they had squares, they had plumb-lines, they had scales, and all that sort of thing just as we have. Suppose an Egyptian wished to determine the time of an equinox. He would first of all make a platform quite flat; he could do that by means of the square or plumb line; then he would get a ruler with pretty sharp edges (and such rulers are found in their tombs), and in the morning of any day he would direct this ruler to the position of the sun when it is rising and he would draw a line; he would do the same thing in the evening when the sun set; he would bisect the angle made by these two lines, and it would give him naturally the north and south points, and a right angle to those would give him the east and west. So that from observation of the sun on any two days in the year he would practically be in a position to determine the position at which the sun would rise and set at the equinox.

There is another way of doing it. Take a vertical rod. Suppose that the sun is rising, let the rod throw a shadow; mark the position of the shadow; at sunset we again note where the shadow falls. If the sun rises exactly in the east and sets exactly in the west, those two shadows will be continuous and we shall have made an observation at the absolute equinox. But suppose the sun not at the equinox, a line joining the ends of the shadows equally long before and after noon will be an east and west line.

It is true that there may be a slight error unless we are very careful about the time of the year at which we make the observations, because when the sun is exactly east or west at the time of rising or setting it is moving most rapidly. So it is better to make the above observations of the sun nearer the solstices than the equinoxes, because the sun changes its declination most quickly at the equinoxes.

Such a rod as this, which I may state is sometimes called a *gnomon*, may be used with another object in view: we may observe the length of the shadow cast by the sun when it is lowest at the winter solstice, and when it is highest; at these two positions of the sun obviously the lengths of the shadows thrown will be different. When the sun is nearest overhead in the summer the shadow will be least, when the sun is most removed from the vertical the shadow will be longest.

The day on which the shortest shadow is thrown at noon will define the summer solstice; when the shadow is longest we shall have the winter solstice.

This in fact was the method adopted by the Chinese to determine the solstices, and from it very early they found a value of the obliquity of the ecliptic.

It may be said that it is only a statement, and that the record has been falsified; some years ago anyone who was driven by facts to come to the conclusion that any very considerable antiquity was possible in these observations met with very great difficulty. But the shortest and the longest shadows recorded (700 years B.C.) do not really represent the true lengths according to recent knowledge. If anyone had forged these observations he would state such lengths as people would find to-day or to-morrow, but the lengths given were different from those which would be made to-day. Laplace, who gave considerable attention to this matter, determined what the real obliquity was at that time, and proved that the record does represent an actual observation and not one which had been made in later years.

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[1] For Figs. 11–13 I am indebted to the kindness of Mr. Stanley, Great Turnstile, Lincoln's Inn Fields.

The solstices and the equinoxes were therefore in all probability thoroughly known to the Egyptians 4000 years B.C., perhaps even 5000. We are then justified in considering that the temples at Abydos and at Karnak are really solar temples. The Egyptians marked the solstices and the equinoxes not only by their temples but in their calendars, which these temples enabled them to construct. The Chinese had also this knowledge, but we have no information that they possessed it at so early a date.

In the next place, then, I propose to make a special study of the temples at Karnak, because they are those which are most capable of minute investigation. I do this in order to see whether any other indications can be obtained of any higher knowledge possessed by the Egyptians of those early times.

I must again point out that we deal with the solstices in the case of the temples at Abydos and Karnak, and with the equinoxes in the case of the pyramids, some mounds in Babylonia, and the Temple at Jerusalem. Since the labours of the French and Prussian Governments who have given such full records of Karnak, a memoir on the temples has been published by Mariette, which gives us not only plans, but precious information relating to the periods at which, and the kings by whom, the various parts of the temples were constructed or modified.

We may begin by the general plan of Thebes. We find there a perfect nest of temples. No doubt those which are still traceable form only a very small portion of those which once existed, but however that may be, I have now only to call attention to one or two among them. In the general plan we see indications that on both sides of the Nile there were temples pointing to those special amplitudes which I have before referred to. What we have first to do is to refer to the solstitial temples, those which point to 26° N. or S. of E. or W., in which we have undoubtedly indications of the early attempts to observe, or to worship, the sun at sun-rising and at sun-setting, at the critical times—the solstitial times of the year.

The first point that I wish to make is that these temples—whatever views may be entertained with regard to their worship or the ceremonial in them—were undoubtedly constructed among other reasons for the purpose of obtaining an exact observation of the precise time of the solstice. The priests having this power at their disposal, would not be likely to neglect it, for they ruled by knowledge. The temples were, then, astronomical observatories, and the first observatories that we know of in the world.

If we consider them as horizontal telescopes used for the purpose I have suggested, we at once understand the long axis, and the series of gradually narrowing diaphragms, for, the longer the beam of light used, the greater is the accuracy that can be obtained.

It is worthy of note that the direction of the temple at Karnak is quite independent of the locality, it has nothing to do with the presentation of the temple to the Nile or to any other particular part of the landscape, and that point, I think, is absolutely settled by the consideration that we have temples at the same amplitude in different localities up and down the Nile Valley, where, although they are parallel to each other, their presentation to the river in the different localities is very various.

What then was the real use of these pylons and these diaphragms? It was to keep all stray light out of the carefully roofed and darkened sanctuary; but why was the sanctuary to be kept in darkness?

Independently of ceremonial reasons—there is a good deal to be said under that head—it is quite clear that the darker the sanctuary the more obvious will be the patch of light on the end wall, and the more easily can its position be located. It was important to do this on the two or three days near the solstice in order to get an idea of the exact time at which the solstice took place. We find that a narrow beam of sunlight coming through a narrow entrance some 500 yards away from the door of the Holy of Holies would, provided the temple were properly orientated to the solstice, and provided the solstice occurred at the absolute moment of sunrise or sunset according to which the temple was being utilized, practically flash into the sanctuary and remain there for about a couple of minutes, and then pass away. The flash would be a crescendo and diminuendo, but the whole thing would not last above two minutes or thereabouts, and might be considerably reduced by arrangements of curtains. Supposing the solstice did not occur at the precise moment of sunrise or sunset, and provided the Egyptians by any means whatever were able to divide the days and the nights into more or less equal intervals of time, two or three observations of the sun-rising at the solstice on three different mornings, or of the sunset at the solstice on three different evenings, would enable a careful observer to say whether the solstice had occurred at the exact moment of sunrise or at some interval between two successive sunrises, and if the latter, what that interval was.

I now come to my next point, which is that here we have the true origin of our present means of measuring time—that our year as we know it was first determined in these Egyptian temples and by the Egyptians. We have seen that it did not require any great amount of astronomical knowledge to determine either the moment of the solstice or the moment of the equinox. I think you will agree with me that the most natural thing to begin with was the observation of the solstice, for the reason that at the solstice you can watch the sun day after day getting more and more north or more and more south until it comes to a standstill. But for the observation of the equinox, of course, the sun is moving most rapidly either north or south, and therefore it would be more difficult to determine in those days the exact moment, so that I have little doubt that what they attempted in the first instance was to mark the absolute moment of the solstice. If that be so, and if Maspéro is right that Abydos was built before Menes, then we know definitely that the Egyptians could and did observe the solstices, and knew what they were doing, 7000 years ago.

Before I say anything more about the use of these temples in determining the year, it is worth while to note how very different the treatment of this subject was in Egypt to what it was in Chaldæa and Babylonia and among the Jews. We do of course in the Egyptian inscriptions read of the moon, but in Chaldæa it would seem that the moon was the chief thing worshipped, and it was thus naturally the chief means used for measuring time, and, as far of course as months were concerned, this was quite right. In Chaldæa, where they were not dependent upon the rising of the Nile, and where much desert travel had to be undertaken at night, the moon and the month were the points considered, and the sun was hardly regarded at all from that point of view. An interesting point connected with this is that, among any of these ancient peoples, the celestial bodies which gave them the longest period of time by which they reckoned were practically looked upon in the same category.

Thus, for instance, in Egypt the sun being used, the unit of time was a year; but in Chaldæa the unit of time was a month, for the reason that the standard of time was the moon. So that when people began speaking about periods of time it was quite easy for one nation to conceive that a period of time was a year when really it was a month, and *vice versâ*. It has been suggested that the years of Methuselah and other persons who are stated to have lived a considerable number of years were not solar years but lunar years—that is, properly, lunar months. This is reasonable, since if we divide the numbers by 12 we find that they come out very much the same length as lives are in the present day.

The Egyptians, taking the sun as their measurer of time, began very early with a year of 360 days. For some reason or other they divided these 360 days into months, probably with some lunar connection, so that they had 12 months of 30 days. Now, we know that that is not the true length of the year, and it is clear that any nation which uses such a year as that will find its festivals going through the year. Further, such a year as that is absolutely useless for the agriculturist or the gardener, because after a time the same month, to say nothing of the same day of the month, will not mean reaping-time, will not mean sowing-time, or anything else. So that this 360-day year did not last very long; so long as it lasted, however, they knew that they got the seasons back to months of the same name in a period of 70 years.

This method led to complications, which possibly may have had something to do with the building of these temples. Egypt being exclusively the gift of the Nile, you can quite understand that their earliest calendar would be connected with the Nile, and so one finds it. We and other peoples occupying the zone in the north divide the year into four seasons; the Egyptians divided it, and still divide it, into three: they have four months of the flood of the Nile, then they have four months after the Nile has retired, in which they do their sowing, and then they have other four months which they call their summer, in which they gather their harvest.

We began, then, with a year of 360 days, and, having 360 days instead of $365\frac{1}{4}$, we had a cycle of 70 years, and during that cycle each day of the year meant something different with regard to the advance of the seasons, and with regard to the work of the agriculturist and the gardener to what it had meant in the preceding year. But this state of things did not last long. The 1st of the first month fell at the summer solstice on June 20, and the reason that it fell then was, that the inundation of the Nile reached Memphis on that day. Whether with the help of the temples or not, they soon got very much nearer, and changed the year of 360 for one of 365 days, which is, roughly, within a quarter of a day of the truth. They had still their 12 months of 30 days, and then they added an extra month of 5 days. With their perfectly orientated temples they must have soon found that their festival at the summer solstice—which festival is known all over the world to-day—did not fall precisely on the same day of the new year, because, if 365 days had exactly measured the year, that flash of bright sunlight would have fallen into the sanctuary just as it did 365 days before. But what they must have found was, that after an interval of four years it did not fall on the first day of the month, but on the day following it. They at once faced this, and found out that 365 days did not exactly make a year, but that they had to do with a quarter day in addition. What the Chinese did was this: every fourth year, instead of adding 5 days to their 360, they added 6 days, and in that way they practically brought the calendar right.

Theory indicated that retaining the 365-day year, the 1st of the first month would come back to its exact relationship to the inundation of the Nile after a period of 1460 years, the 1460 years of course depending upon the quarter being added ($365 \times 4 = 1460$).

This was known in Egypt to the priests alone. They would not allow the year of 365 days, called the *vague* year, to be altered, and so strongly did they feel on this point that every king had to swear when he was crowned that he would not alter the year. We can surmise why this was. It gave great power to the priests; they alone could tell on what particular day of what particular month the Nile would rise in each year, because they alone knew in what part of the cycle of 1460 years they were, and in order to get that knowledge they had simply to continue going every year into their Holy of Holies one day in the year as the priests did in Jerusalem, and watch the little patch of bright sunlight coming into the sanctuary. That would tell them exactly the relation of the true solar solstice to their year, which was supposed to begin at the solstice, and the exact date of the inundation of the Nile could be found by those who could determine observationally the solstice, but by no others.

In reading books on Egypt we come across another cycle which is supposed to be a very mysterious one; in fact it is one which, I think, has not yet been sufficiently investigated, and it is very well worth the trouble of anybody who will give the time. They begin with a year of twelve months, each of which has thirty days, thus giving 360 days; this was found not to work. They then tried 365 days, but that also would not work, because then the first day of Thoth (their first month) would only indicate the inundation of the Nile one year out of 1460; and then the priests interpolated the other day and got the cycle right, but it was not yet quite right. In the time of Hipparchus 365·25 did not really represent the true length of the solar year; instead of 365·25 we must write 365·242392—that is to say, the real length of the year was a little less than $365\frac{1}{4}$ days.

Now the length of the year being a little less, of course we should only get the absolute coincidence of the 1st of Thoth with the inundation of the Nile in a longer period than the 1460 years cycle; and, as a matter of fact, the 1460 years had to be expanded into 1506 to fit the months into the years with this slightly shortened length of the year; so we have a period which is called *sothic*, of 1460 years; and a period which is called *phœnix*, of 1506 years.

There is a great wealth of interest connected with the uses of the temples from the point of view of worship, but that does not concern us here, except that it is intimately connected with the next part of the subject, for I have next to point out that it necessitated in Egypt, Chaldæa, and elsewhere contemporaneous observations of the stars. I therefore now pass from the sun to the stars.

J. NORMAN LOCKYER.

(*To be continued.*)

## *FORESTRY IN NORTH AMERICA.*

IN continuation of the notes under the above heading which appeared in NATURE last January, I wish to refer to a splendid paper[1] recently read by Sir Dietrich Brandis, F.R.S., to the Natural History Society of Bonn. It consists chiefly of a compilation from Dr. Mayr's book, "Die Waldungen von Nord America" (Munich, 1890), and from works by Prof. Sargent Bernhard Fernow, the present Chief of Forestry at Washington, and some other authors, as well as from the Agricultural Reports of the United States.

Dr. Mayr is the son of a Bavarian State forest officer, and, after studying forestry and botany at Munich, he was sent, at the expense of the Bavarian Government, to observe in their native forests, at different ages, certain important

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[1] "Der Wald in den Vereinigten Staaten von Nord America," von Dr. D. Brandis in Bonn, 1891. (Sonder Abdruck aus den *Verhandlungen des Naturhistorischen Vereins*, 47 Jahrg.)